METHOD AND DEVICE FOR PERFORMING INTER-VEHICLE DISTANCE CONTROL

[0001] The invention relates to a method and a device for performing inter-vehicle distance control on a vehicle, an actual value of a distance variable which describes a distance between the vehicle and a vehicle traveling in front being determined and in which a plurality of weighting values for the distance variable are determined as a function of input variables which describe the driving situation of the vehicle and/or the ambient situation of the vehicle and/or the driving behavior of the driver, the weighting values being combined in a first computing step to form a combined value for the distance variable. From which combined value in turn a set point value for the distance variable is determined, braking means and/or driving means of the vehicle being actuated in such a way that the determined actual value of the distance variable assumes the determined set point value of the distance variable.

[0002] Such a device for inter-vehicle distance control is based on the publication DE 199 43 611 A1. The device determines a set point distance from a vehicle traveling in front, the driving speed of the vehicle being controlled by interventions into the engine drive and/or the brakes of the vehicle in such a way that the distance between the vehicle and a vehicle traveling in front assumes the determined set point distance. So that a safe, that is to say sufficiently large, distance from the vehicle traveling in front is maintained even under unfavorable weather conditions and light conditions, weighting values are determined as a function of input variables which describe the driving speed, the visibility, the state of the road, the activity of the windshield wipers and the switched state of fog lights and headlights, and the said weighting values assume larger positive values the more unfavorable the weather conditions and light conditions which are described by the input variables. The weighting values constitute, according to one illustrated exemplary embodiment, dimensionless relative values which are added to form a common factor in accordance with which the set point distance is made larger when there are unfavorable weather conditions and light conditions. It is disadvantageous that the addition of further weighting values which result from input variables which are to be additionally taken into account leads under certain circumstances to an inappropriately large set point distance from the vehicle traveling in front.

[0003] The object of the present invention is therefore to develop a method and a device of the type mentioned at the beginning in such a way that any desired number of input variables can be taken into account in order to determine the set point value of the distance variable without the possibility of an inappropriate set point value being produced for the distance variable.

[0004] This object is achieved according to the features of patent claim 1 and of patent claim 7, respectively.

[0005] According to the invention for performing inter-vehicle distance control on a vehicle, an actual value of a distance variable which describes a distance between the vehicle and a vehicle traveling in front is determined. Furthermore, a plurality of weighting values for the distance variable are determined as a function of input variables which describe the driving situation of the vehicle and/or the ambient situation of the vehicle and/or the driving behavior of the driver, the weighting values being combined in a first computing step to form a combined value for the distance variable. In turn a set point value for the distance variable is determined from the combined value, braking means and/or driving means of the vehicle being actuated in such a way that the determined actual value of the distance variable assumes the determined set point value. The first computing step is followed by a second computing step in which the combined value is restricted to a predefined value range, the set point value of the distance variable being determined from the combined value which is restricted if appropriate. The subsequent restriction of the combined value permits, on the one hand, any desired number of input variables to be taken into account in order to determine the set point value of the distance variable without the possibility of an inappropriate set point value being produced for the distance variable, and on the other hand permits wide ranging freedom in the selection of the combination function which is used to determine the combined value, since the combination function itself does not need to have any restriction.

[0006] The input variables which are used to describe the driving situation of the vehicle and/or the ambient situation of the vehicle and/or the driving behavior of the vehicle comprise, in particular, one or more of the following variables:

- the windshield wiper activity, the velocity and acceleration of the vehicle, the relative velocity and relative acceleration between the vehicle and vehicle traveling in front,

- the profile of the carriageway, the inclination of the carriageway, the condition of the carriageway, applicable speed limits, the weather conditions and light conditions in the surroundings of the vehicle, the external temperature,

- the driving ability of the driver, the type of driver and the activation of an accelerator pedal which is provided to permit the driver to influence the driving means.

[0007] Advantageous embodiments of the method according to the invention emerge from the subclaims.

[0008] The combination of the weighting values is preferably a multiplicative operation. For the sake of clarity it will be assumed that a high weighting value corresponds to a high set point value, and a low weighting value corresponds to a low set point value of the distance variable. Owing to the multiplicative combination, a high weighting value (> 1) can thus be compensated by a low weighting value (< 1), and vice versa. In this case, in particular, highly deviating weighting values which are determined incorrectly can be compensated, which decisively increases the reliability during the determination of the set point value of the distance variable.

[0009] In order to determine the set point value of the distance variable precisely, the multiplicative operation can be the geometric average of the weighting values. The geometric average can be determined on the basis of an easy-to-calculate series expansion, the precision of

the determination being greater the higher the number of series elements which are taken into account.

[0010] In order to prevent the averaged weighting values giving rise to excessively large or excessively small set point values for the distance variable, the combined value is restricted to a predefined value range. The value range is defined here by predefining an upper and lower limiting value for the combined value, the limiting values being predefined as a function of driving state variables which describe the driving state of the vehicle.

[0011] In order to easily determine the set point value of the distance variable it is possible to multiply the combined value by a suitable reference value for the distance variable, the reference value also being predefined as a function of the driving state variables which describe the driving state of the vehicle. The aforementioned driving state variables comprise, for example, a velocity variable which describes the velocity of the vehicle and/or an acceleration variable which describes the acceleration or deceleration of the vehicle and/or a relative velocity variable which describes the relative velocity between the vehicle and vehicle traveling in front and/or a relative acceleration variable which describes the relative acceleration or relative deceleration of the vehicle with respect to the vehicle traveling in front.

[0012] The reference value and the limiting values are preferably determined in such a way that the set point value of the distance variable does not exceed or drop below a given maximum value or minimum value. The maximum value is given essentially by the maximum range of sensor means which are provided for determining the actual value of the distance variable, while the minimum value is obtained from a minimum distance from the vehicle traveling in front which must not be undershot for safety reasons and which is both as short as possible and also, in the case of full braking of the vehicle traveling in front, permits the driver to brake the vehicle safely to a stationary state without a collision, deceleration time variables which describe the reaction time of the driver ("shock second") and/or which describes the delay time of braking means of the vehicle caused by the air play, also being taken into account in addition to the driving state variables. The sensor means are, for example, radar sensors or ultrasonic sound

sensors which are used in customary inter-vehicle distance control systems. The range of the sensor means is between 30 and 200 meters depending on the design and the frequency range used.

[0013] In order to inform the driver that he is driving too close to the vehicle traveling in front or that there is a risk of a rear-end collision, it is possible to issue a driver warning to the driver of the vehicle in the form of visual and/or audible signals if the determined actual value of the distance variable drops below the set point value of the distance variable, that is to say the minimum value of the distance variable, which is given by the lower limiting value of the combined value. The driver then still has sufficient time to take suitable counter measures, for example by activating the braking means of the vehicle.

[0014] The method according to the invention and the device according to the invention will be described below in more detail with reference to the appended drawings, in which:

[0015] fig. 1 is the schematic illustration of an exemplary embodiment of the method according to the invention, and

[0016] fig. 2 is a schematically illustrated exemplary embodiment of the device according to the invention.

[0017] Fig. 1 illustrates an exemplary embodiment of the method according to the invention for performing inter-vehicle distance control on a vehicle, an actual value d_{act} of a distance variable which describes a distance between the vehicle and a vehicle traveling in front being determined in a first main step 11. At the same time, a plurality of weighting values $g_{i,i=1...4}$ are determined for the distance variable in substeps 12a to 12d which are part of a second main step 12, as a function of input variables $x_{i,i=1...4}$ which describe the driving situation of the vehicle and/or the ambient situation of the vehicle and/or the driving behavior of the driver.

[0018] For example, a first input variable x_i is a variable which describes an accelerator pedal deflection s, caused by the driver, of an accelerator pedal (not illustrated) which is provided to permit the driver to influence driving means of the vehicle. If a risk of a rear-end collision with a vehicle traveling in front suddenly occurs, the driver intuitively reacts by reducing the accelerator pedal deflection s with a view to increasing the distance from the vehicle traveling in front to a safe value. Conversely, if the accelerator pedal deflection s is increased the driver intuitively expects the distance from the vehicle traveling in front to be decreased. The first weighting value g_i is therefore greater the larger the accelerator pedal deflection s caused by the driver, which comes about in the first substep 12a as a result of the use of a corresponding functional dependence between a first weighting value g_1 and the accelerator pedal deflection s. The functional dependence has in this respect in particular the illustrated step-shaped profile, in which case of course any other profile which leads to the desired result is also conceivable instead of a step-shaped profile. In the preferred exemplary embodiment, the steps of the profile according to the first substep 12a each have a hysteresis.

[0019] In a second input variable x_2 is a variable which characterizes the driving ability of the driver. The driving ability is specified or predefined, for example, by the driver of the vehicle at an operator control element which is arranged in the vehicle, the driver being able to select between a "comfort mode" and a "sporty mode". The second weighting value g_2 is greater in the "comfort mode" than in the "sporty mode" which is taken into account in the second substep 12b during the determination of the second weighting value g_2 by using a corresponding functional dependence between the second weighting value g_2 and the selected mode. For example, the functional dependence is described by a jump function. Of course, it is also possible to provide more than two selectable modes. Furthermore, it is also possible to conceive of the driving ability being estimated independently of the driver by evaluating suitable variables, for example by evaluating the maximum occurring accelerations or decelerations a_f of the vehicle or of the activation speed of operator control elements which are provided for influencing the longitudinal and lateral dynamics of the vehicle.

[0020] Furthermore, a third input variable x_3 is a variable which characterizes the state of the road, that is to say the coefficient of friction μ between the surface of the carriageway and the wheels of the vehicle. The third weighting value g_3 has a tendency to increase as the coefficient of friction μ becomes smaller, which is taken into account in the third substep 12c in the form of a corresponding functional dependence between a third weighting value g_3 and a coefficient of friction μ. The coefficient of friction μ is determined, for example, on the basis of a determined velocity variable which describes the velocity v_f of the vehicle, and/or a determined yaw rate variable which describes the yaw rate $\dot{\psi}$, and/or a determined lateral acceleration variable which describes the lateral acceleration a_y acting on the vehicle, and/or a determined steering angle variable which describes the steering angle δ which is set at steerable wheels of the vehicle. Alternatively, the coefficient of friction μ is merely estimated, for which purpose the windshield wiper activity and/or the external temperature are evaluated.

[0021] Finally, a fourth input variable x_4 is a variable which describes the acceleration behavior of the vehicle traveling in front in relation to the driver's own vehicle, that is to say, for example, a relative acceleration variable which describes the relative acceleration or relative deceleration a_{rel} of the vehicle in relation to the vehicle traveling in front. The fourth weighting value g_4 becomes larger or smaller here the higher the acceleration or deceleration of the vehicle traveling in front relative to the driver's own vehicle, which is taken into account in the fourth substep 12d by using a corresponding functional dependence between a fourth weighting value and relative acceleration or relative deceleration a_{rel}. The functional dependence has, in particular, the illustrated step-shaped profile, in which case of course any other profile is also possible instead of a step-shaped profile.

[0022] In a way which is analogous with the first substep 12a, the steps of the profile which are illustrated in the fourth substep 12d also each have a hysteresis. The hysteresis avoids already small fluctuations in the input variable x_1 or x_4 in the region of one of the jump points of the step-shaped profile leading to continuous changing to and fro between two adjacent step levels of the weighting value g_1 or g_4, which would ultimately result in an extremely unsteady inter-

vehicle distance behavior of the vehicle with respect to the vehicle traveling in front owing to the continuously changing set point value of the distance variable.

[0023] The weighting values $g_{i,i=1...4}$ in the present exemplary embodiment constitute dimensionless factors which lie within predefined value intervals, the value intervals each being defined by the predefinition of an upper interval limit $g^{max}_{i,i=1...4}$ and of a lower interval limit $g^{min}_{i,i=1...4}$. In terms of order of magnitude, for example $g^{max}_{i,i=1...4} \approx 1.0 ... 1.5$ and $g^{min}_{i,i=1...4} \approx 0.5 ... 1.0$. The precise value of the interval limits $g^{max}_{i,i=1...4}$, $g^{min}_{i,i=1...4}$ depends on the respective input variable $x_{i,i=1...4}$.

[0024] The precise functional dependencies between the weighting values $g_{i,i=1...4}$ and the input variables $x_{i,i=1...4}$ are determined, like the respectively associated value intervals or interval limits, on the basis of theoretical investigations and/or simulations and/or driving trials.

[0025] In a first computing step, the determined weighting values $g_{i,i=1...4}$ are combined to form a combined value f for the distance variable. This is carried out in a third main step 13, in which case the combination is a multiplicative operation,

[0026]
$$f \propto \prod_{i=1...4} g_i ,$$

[0027] preferably the geometric average of the weighting values $g_{i,i=1...4}$,

[0028]
$$f \propto \sqrt[4]{\prod_{i=1...4} g_i} .$$

[0029] In a second computing step, the combined value f is restricted to a predefined value range. This takes place in a fourth main step 14, the value range being defined by a predefining an upper limiting value f_{max} and a lower limiting value f_{min} for the combined value f. The limiting values f_{max}, f_{min} are predefined as a function of driving state variables which describe the driving state of the vehicle. In terms of order of magnitude, the following applies, by way of example, $f_{max} \approx 1.75$ and $f_{min} \approx 0.25$.

[0030] In order to determine the set point value d_{setp} of the distance variable, the combined value f, which is limited if appropriate, is multiplied, in a fifth main step 15, by a suitable reference value d_{ref} of the distance variable, the reference value d_{ref} also being predefined as a function of driving state variables which describe the driving state of the vehicle. In a modification of the illustrated embodiment, it is also possible to limit the set point value d_{setp} of the distance variable instead of limiting the combined value f.

[0031] The driving state variables are, for example, a velocity variable which describes the velocity v_f of the vehicle, and/or an acceleration variable which describes the acceleration or deceleration a_f of the vehicle, and/or a relative velocity variable which describes the relative velocity v_{rel} between the vehicle and vehicle traveling in front, and/or a relative acceleration variable which describes the relative acceleration or relative deceleration a_{rel} of the vehicle with respect to the vehicle traveling in front.

[0032] The reference value d_{ref} and the limiting values f_{max}, f_{min} are preferably determined in such a way that the set point value d_{setp} of the distance variable does not exceed or drop below a given maximum or minimum value. The maximum value is given essentially by the maximum range of sensor means which are provided for determining the actual value d_{act} of the distance variable, while the minimum value results from a minimum distance from the vehicle traveling in front which must not be undershot for safety reasons and which is both as short as possible and also, in the case of full braking of the vehicle traveling in front, permits the driver to brake the vehicle safely to a stationary state without a collision, deceleration time variables based on empirical values which describe the reaction time of the driver (“shock second”) and/or which

describe the delay time of braking means of the vehicle caused by the air play, also being taken into account in addition to the driving state variables.

[0033] Finally, in a sixth main step 16, the braking means and/or the driving means of the vehicle are actuated in such a way that the determined actual value d_{act} of the distance variable assumes the determined set point value d_{setp}. This is done in the form of the closed-loop or open-loop control operation, the difference, i.e. the deviation between the actual value d_{act} and the set point value d_{setp} of the distance variable, forming an open-loop or closed-loop control variable for actuating the braking means and/or the driving means.

[0034] In order to inform the driver that he is driving too close to the vehicle traveling in front or that there is a risk of a rear-end collision, in a second secondary step 22 a driver warning is issued to the driver of the vehicle in the form of visual and/or audible signals if it is detected in a preceding first secondary step 21 that the determined actual value d_{act} of the distance variable drops below the set point value d_{setp} of the distance variable, that is to say the minimum value of the distance variable, which is given by the lower limiting value f_{min} of the combined value f.

[0035] Fig. 2 shows an exemplary embodiment of the device according to the invention for performing inter-vehicle distance control on a vehicle. The device comprises of the sensor means 30 which are provided for sensing the distance between the vehicle and a vehicle traveling in front and an evaluation means 31 to which the distance signals of the sensor means 30 are fed. The sensor means 30 are, for example, radar sensors or ultrasonic sound sensors such as are used in customary inter-vehicle distance control systems. At the same time, the evaluation unit 31 determines the weighting values $g_{i,i=1...4}$ of the distance variable on the basis of the input variables $x_{i,i=1...4}$. The functional dependencies which are required to determine the weighting values $g_{i,i=1...4}$ are stored here in the evaluation unit 31.

[0036] The accelerator pedal deflection s which is used to determine the first weighting value g_i is in the form of a sensor signal which is provided by an accelerator pedal sensor 34 which interacts with the accelerator pedal 32, and is supplied to the evaluation unit 31.

[0037] Furthermore, in order to determine the second weighting value g_2, the evaluation unit 31 senses the switched state of the operator control element 35 which is provided for predefining the driving ability and which permits selection between the "comfort mode" and the "sporty mode". The operator control element 35 is preferably implemented in an existing combination menu unit and is controlled by a menu.

[0038] In order to determine the third weighting value g_3 on the basis of the state of the road, that is to say the coefficient of friction μ, the evaluation unit 31 evaluates the signals of wheel speed sensors 40 which sense the wheel speeds $n_{i,i=1...4}$ of the wheels of the vehicle, and/or of a yaw rate sensor 41 which senses the yaw rate $\dot{\psi}$ of the vehicle, and/or of a lateral acceleration sensor 42 which senses the lateral acceleration a_y acting on the vehicle, and/or a steering wheel angle sensor 43 which senses the steering wheel angle α of a steering wheel 44 which is provided in order to permit the driver to influence the steering angle δ. In particular the velocity variable or the velocity v_f of the vehicle which is described by the velocity variable can be derived from the sensed wheel speeds $n_{i,i=1...4}$. Both the yaw rate sensor 41 and the lateral acceleration sensor 42 may be part of an electronic stability program (ESP) which is present in the vehicle. Alternatively, the evaluation unit 31 can estimate the coefficient of friction μ by evaluating the signals of a windshield wiper sensor 45 which is provided for sensing the windshield wiper activity, and/or of a temperature sensor 46 which is provided for sensing the external temperature.

[0039] Finally, the relative acceleration or relative deceleration a_{rel} which is used to determine the fourth weighting value g_4 is obtained by double derivation over time or corresponding formation of gradients for the distance signals which are made available by the sensor means 30.

[0040] The weighting values $g_{i,i=1...4}$ which are determined as a function of the input variables $x_{i,i=1...4}$ are combined by the evaluation unit 31 in a multiplicative fashion to form the combined value f for the distance variable, then limited to the value range defined by the upper and lower

limiting values f_{min}, f_{max}, and finally multiplied by the predefined reference value d_{ref} of the distance variable in order to determine the set point value d_{setp} for the distance variable.

[0041] After the set point value d_{setp} of the distance variable has been determined, the evaluation unit 31 actuates the braking means 50 which are provided to brake the vehicle and/or the driving means 33 in such a way that the determined actual value d_{act} of the distance variable assumes the determined set point value d_{setp}. For this purpose, the evaluation unit 31 interacts with a driving means controller 51 in order to actuate the driving means 33, and with a braking means controller 52 in order to actuate the braking means 50, the driving means 33 being, inter alia, an engine, transmission and clutch of the vehicle, and the braking means 50 being, for example, hydraulically or pneumatically activated wheel brake devices.

[0042] In order to output the driver warning to the driver, visual and/or audible signal transmitters 53 are provided which are actuated by the evaluation unit 31 if the determined actual value d_{act} of the distance variable drops below the set point value d_{setp} of the distance variable which is given by the lower limiting value f_{min} of the combined value f.

[0043] The device is activated or deactivated, for example, by means of a switch 54 which is connected to the evaluation unit 31 and which can be implemented in an existing combination menu unit and is controlled by a menu. In addition, it is also conceivable to deactivate the device independently of the driver if a driver's request for braking of the vehicle is detected, for which purpose the evaluation unit 31 evaluates the signals of a brake pedal sensor 55 which senses a brake pedal deflection 1, caused by the driver, of a brake pedal 56 which is provided to permit the driver to influence the braking means 50.

[0044] The sensors which are necessary to implement the method and the device are generally present in the vehicle so that the inter-vehicle distance control according to the invention can not only be provided cost effectively in new vehicles but also subsequently retrofitted into already existing inter-vehicle distance control systems.